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R.L. Carovillano

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 Proceedings of the 27th Plenary Meeting of the Committee on Space Research, held in Helsinki, are discussed. The discussion includes Soviet cosmonaut J. Romanenko's account of his epic space flight, interagency coordination of missions, and summaries of many papers under the heading of auroral topics.

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COSPAR MEETS IN HELSINKI

Introduction

The Committee on Space Research (COSPAR) held its XXVII Plenary Meeting at the Helsinki University of Technology in Espoo, Finland, from 18 through 29 July 1988. COSPAR is a committee of the International Council of Scientific Unions, charged with promoting basic space science (not technology) on a broad scale. Perhaps the principal means of fulfilling its charge, COSPAR conducts biennial international meetings relating virtually to all areas of space research including results gotten from satellites, space probes, balloons, rockets, and ground-based observations. Accordingly, the purview of the meeting is vast, extending from the lower atmosphere upwards and outwards to the sun, the solar system, and into the astronomical and astrophysical regimes. Remote sensing of the earth and space studies of the earth's surface and atmosphere are also included. The Helsinki meeting had about 16 symposia, 25 workshops, 23 topical meetings, a special session entitled "Solar-Terrestrial Energy Programme (STEP) - Major Scientific Problems," and many planning sessions for future meetings. Each scheduled meeting normally included invited and contributed talks, a selection of which would be published in summary form in the official COSPAR journal, *Advances in Space Research* (symposia, workshops, topical meetings), published by Pergamon Press.

STEP is an international program, organized by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) and chaired by J. G. Roederer (University of Alaska), that will take place in the years 1990-1995. The purpose of STEP is the investigation of energy production, transfer, storage, and dissipation in and by the solar-terrestrial environment.

There were about 1400 registrants to the COSPAR conference with about 5 percent no-shows. The largest national representation was from the US (about 425) but the total European presence was perhaps twice as large. In particular, West Germany (147), France (123), and Finland (106) had large representations. An uncommonly large number of Soviets (about 30) were preregistered for the meeting, but few actually attended and delivered papers.

In this report highlights will be given of talks from several of the symposia and from two special presentations: one by the Soviet cosmonaut J. Romanenko, who described his experiences in space, and one by Stanley

Shawhan, head of the Space Physics Division at NASA headquarters, who spoke on the international coordination of space missions in solar-terrestrial science over the next decade.

Romanenko Space Account

At a well-attended evening session, the Soviet cosmonaut J. Romanenko, who in December 1987 completed a record 326 consecutive days in space aboard the MIR space station, gave a general description of his space experiences and responded to open questions from the audience. His tasks in the near-earth orbit station were in four areas: (1) monitoring and tending to technical needs of the station, including the installation of a new solar panel; (2) conducting astrophysical observations; (3) remote sensing of the earth including observations of natural resources and atmospheric processes; (4) tending to numerous biotechnological tasks, and undergoing many medical and biological examinations to monitor and test the human ability to endure long-term space flights.

Romanenko stated that scientific experimentation and knowledge were the primary purposes of the mission. Science activities included x-ray, ultraviolet, and cosmic ray observations; observation of a supernova; studies of mineral, fuel, and gas resources; examination of geological structures, harvest prospects; viewing urban contamination; conducting semiconductor and thin-film experiments; the measurement of conductivity and dielectric changes of materials in space; and performing blood purification and gene experiments. The mission's cosmonauts were subjected to 34 different medical examinations. Tests included: cardiovascular system monitoring during rest and exercise; metabolism rates, acidity of stomach fluids, oxygen content in body tissue; femor volume and weight; fluctuations in total body mass.

Romanenko made a total of 1305 observations and performed 273 scientific experiments. A microscope was used for hemological observation. Tasks were numerous, many were complex, and his days were very busy. Romanenko stated that good habits, regular work and sleep, eating and exercising properly were important for his well-being in space and his rapid recovery after the mission on earth.

In response to a question, Romanenko stated the reports in the Italian and English presses of after-flight health problems were unfounded and incorrect. Two months after the flight, only slight and unimportant biological changes were found in his system and none required special treatment.

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Questions were asked whether a manned flight to Mars wouldn't involve human problems with regard to duration and adjustment to Mars' gravity. Romanenko pointed out that the trip to Mars would take about 270 days, which is considerably less than his recent stay in space, and that the Mars gravitational field is much weaker than at Earth. Thus, he was optimistic with regard to human factors. Other mission problems might be more serious. Regarding exposure to radiation in space, Romanenko was unaware of his total exposure but indicated that such data would be reported upon at the biomedical sessions of the conference. He stated that his exposure was less than would be typical of certain industrial environments and that he was not concerned on the matter. Other questions on radiation exposure were in relation to the dangers of a trip to Mars, particularly during solar maximum conditions when radiation levels in space can be very high and the occurrence of solar flares more frequent, and to orbital flights to high geomagnetic latitudes when the satellite would pass through the South American magnetic anomaly. Romanenko persisted in his lack of concern stating that radiation levels are monitored carefully and that adequate precautions would be taken in the future as in the past. With regard to his optimism, Romanenko said that a cosmonaut who is not optimistic should change jobs.

The final question was whether Romanenko felt that his role in space was indispensable. Romanenko gave a straightforward reply. In the medical and biotechnology areas his role was certainly unique and critical. On the other hand, most of the space experiments were not conducted for the first time. With regard to the need for unexpected adjustments and repairs in space, the cosmonauts played a very useful role. In supplementary comments on the scientific discoveries made on the MIR space station, R. A. Sunyaev (Deputy Head, Space Research Institute, Moscow) emphasized that it was useful to work with the cosmonauts in real time in performing experiments. Ground experimenters found it to be a great asset to be able to speak to the working cosmonauts. Improved aiming of telescopes, detector repair or adjustments, and tending to unexpected problems took place.

In reviewing science accomplishments from MIR, Sunyaev emphasized the x-ray observations which extended up to an energy of 1 MeV. Measurements included the hardest x-ray observation ever made in space and isotopic ratio variations of cobalt that suggested the death stages of a star were being observed in time. The MIR station accomplished pointing accuracy and stability by almost an order of magnitude better than engineers had anticipated. About 1300 different sources were observed, about 25 minutes per star. Very hot stars were found, black hole candidates identified, and variations in stellar spin rates measured. The standard complaint of the astronauts was also made, namely, that there was not enough observing time since MIR had so many competing objectives.

Interagency Coordination of Missions

S. Shawhan of NASA Headquarters spoke on the "Coordination of Future Solar Terrestrial Science: a New Interagency Thrust" on behalf of the Inter-Agency Consultative Group (IACG) and gave an overview of what the solar-terrestrial spacecraft environment may be in the 1990's. The membership of the IACG consists of the four major space agencies: the Soviet Space Research Institute (IKI), the Japanese Institute for Space and Astronomical Science (ISAS), the European Space Agency (ESA), and NASA. The IACG is an informal interagency working group not sanctioned by the governments of the agencies involved and not bound by treaties or memoranda of understanding. The working group functions to coordinate operations and data exchange on behalf of the solar-terrestrial science community and the agencies involved. In the past, the IACG successfully coordinated the Comet Halley mission which involved several spacecraft and nations, and it next will emphasize coordination of programs relating to solar-terrestrial relationships. In addition, panels will be formed to discuss future coordination in astrophysics and planetary science, such as in the space long-baseline interferometry area or a mission to Mars, the Moon, or to small bodies in the solar system.

The perspective on solar-terrestrial relationships is very broad and includes studies of the sun, the solar wind, and particularly the earth's magnetosphere, though the study of other magnetospheres and bodies in the solar system is not excluded. Simultaneous measurements from a variety of spacecraft have become the basic requirement of the field. The IACG will only coordinate activities among already approved space missions to enhance the scientific yield. Exchange of information about future plans will take place but coordination efforts begin only for approved missions. Since IACG is an agency-founded group, the heads of its delegations will be the major space science officials of each agency (Galeev and Sagdeev, IKI; Nishimura and Nishida, ISAS; Bonnet and Reinhard, ESA; and Fisk and Shawhan, NASA). It is rare to have such high officials meeting together, and such involvement should serve to promote coordination and perhaps attract resources to the program.

In addition to spaceflight missions, IACG will interface with special efforts and programs such as STEP. A member of STEP will be invited to attend IACG meetings as an observer.

By the mid-1990's, at least 20 and as many as 30 satellites will be in place. This count does not include space stations, free-flying platforms, additional small US missions (the Explorer program) and other missions that may come out of the other agencies. Shawhan displayed enthusiasm and optimism in describing the unprecedented capability that will be available for studies of solar variability, interplanetary space, planetary environments, the earth's magnetosphere in multisatellite format in the polar regions through the deep geotail, and the upper at-

mosphere. Detailed cause and effect studies would be possible such as the upper atmospheric or magnetospheric response to a solar event observed and documented in detail. The IACG will function as a facilitating organization, not a forcing function, responding to the needs of the scientific community through an iterative feedback process. The community will have rather direct access to the policy makers and funding agencies—a rare opportunity. The IACG will provide the scientific community access to information and inform it of the data base acquired and its availability. In return, scientists can perform multisatellite studies or organize workshops on past-event studies, or plan future experiments or campaigns from the multisatellite system operating.

Auroral Topics

J. S. Murphree (University of Calgary, Canada) reported on VIKING imaging results and correlative ground base data. In the development of substorms, no auroral evidence was found of the so-called poleward leap. Although the polar cusp is not defined by discrete features, discrete intensifications were observed at the poleward edge of the cusp that moved eastwards towards the afternoon sector. Speculation was that the optical effect seen was perhaps a merging signature. A reconnection velocity of 100 km/sec would give a speed of about 2.0 km/sec at the ionospheric footprint, which would be consistent with the observed optical signatures that persisted for about 10 minutes. The intensifications are by a factor of two or so, which is not dramatic and did not allow Murphree to suggest that the observed signature implied intermittent reconnection. Under specific interplanetary field (IMF) conditions (B_z positive, away sector) the development of a polar cap arc was observed to develop across the morning sector after the poleward-cap cusp intensifications ceased.

L. A. Frank (University of Iowa) stated that good comparisons of auroral images from the DE and VIKING satellites are not feasible until VIKING intensities can be quantified. Frank reported on isolated substorm studies made with DE-images on the size of the polar cap. Utilizing a magnetic field model, the size of the polar cap gives a direct measure of the magnetic energy contained in the geomagnetic tail. The shape of the polar cap as defined by the poleward edge of the global auroral image is not a circle, as previously reported, and can be irregularly shaped. The polar cap area is in the range $5-6 \times 10^6 \text{ km}^2$. Using the Coroniti-Kennel tail flaring model, the magnetic energy in the tail is a few times 10^{22} ergs, and the rate of energy change was found to be not impulsive and a few times 10^{19} ergs/sec. The polar cap area increased gradually by 20-40 percent over a time of 30-40 minutes, reaching a maximum at substorm onset and decreasing gradually over the next 30-50 minutes to pres-

torm values. The inferred rate of magnetic flux change in the tail is about 5×10^{12} Maxwells/sec. The polar cap does not expand or recover uniformly. In the early stages of the substorm, most change is on the nightside. The recovery stage involves mainly the nightside and morning sectors, suggesting large-scale regimes of flux transfer in the tail. In the process, little change takes place on the dayside.

P. E. Sandholt (University of Norway, Oslo) reported on transient E-layer emissions and diffuse F-layer emissions in the polar cusp. Cusp arcs are found to be transient on a time scale of 10 minutes and intensifications at the equatorial cusp boundary are found to move poleward. The observed routines seem to be IMF-controlled and consistent with merging expectations at the subsolar point and with properties of flux transfer events (FTEs).

J. D. Craven (University of Iowa) discussed the auroral response to variations in the IMF and the solar wind. For B_z positive the theta aurora occurs in either cap. For B_y , also positive, in the southern polar cap the theta aurora formed in the evening sector and moved as a sustained large-scale feature towards the morning sector over a 2-hour period. In the northern hemisphere, the motion proceeded in the opposite direction from morning to evening (in the B_y direction). Mapping the auroral motions into the tail suggests that the bifurcated tail lobes move in opposite directions. In another example, after a shock wave encountered the magnetopause, the quiet auroral oval brightened and a theta aurora developed across the polar cap at about the rate 1.6 km/sec corresponding to plasma in the lobes moving to higher latitudes. The expansion of the auroral zone into the polar cap can evolve from the morning sector, the evening sector, or by symmetric about midnight; the local time development may be dependent on the IMF.

Other papers dealt with optical pulsations in the aurora (G. G. Shepherd, York University, Toronto), coordinated VIKING satellite and rocket studies (I. Sandahl, Swedish Institute of Space Physics (SISP), Kiruna), and satellite-aircraft-radar observations of auroral arcs (L. Block, Royal Institute of Technology, Stockholm). Sandahl pointed out that auroral intensity and field-aligned current (FAC) magnitude do not vary one-to-one. Sharp plasma flow reversals were reported across auroral arcs by Sandahl and Block. In his analysis, Block stated that electrodynamically one cannot distinguish between sun-aligned F-region arcs and ordinary theta auroral arcs. K. Stasiewicz (SISP, Kiruna) used a magnetic field model to map auroral particle and optical features into the distant tail to identify possible source locations. He concluded that polar cap arcs are related to distant discrete plasma structures in the tail and suggested that discrete polar cap structures are generally related to gradient structures in the magnetosphere depending on distributed currents and the IMF. Using satellite and ground-based data, P. E. Sandholt (University of Oslo, Norway) stated that persistent discrete arcs occur in the polar cleft region, but

only transient arcs occur in the polar cusp. At the poleward edge of the cleft, discrete arcs persist for longer than 20 minutes with IMF B_z positive. The folds in the poleward arc are interpreted to carry FAC's of alternating polarity (out of or into the ionosphere) and give rise to observed cleft emissions in space. An effort to detect corresponding ground pulsations had not been made.

The AFGL paper on the statistical dependence of ion precipitation at auroral latitudes on the IMF and solar wind speed (v_{sw}) was presented by D. Smart. With a vast DMSP data base, maps were determined of ion number flux, energy flux, and average energy as a function of IMF B_z , B_y , and v_{sw} . Conditions that best define the ground state of the magnetosphere were found to be $B_z = 1.3 \text{ nT}$ and $v_{sw} = 364 \text{ km/s}$. For cusp properties, results included a decreasing latitude with B_z increasing southwards, an increasing minimum energy with B_z increasing northwards, and a shifting local time with B_y . The AFGL group defines the cusp location by the minimum number flux of precipitating particles. Using VIKING data, R. Lundin (SISP, Kiruna) reported on the statistical studies made of the cusp and cleft during the quiet PROMIS period. The cusp is characterized by high electron fluxes representing structureless precipitation of magnetosheath plasma on open field lines. At best, modest accelerations occur in the cusp. Its latitudinal extent is found to be about 2 degrees (77 to 79 degrees) and its local time extent less than about 10 degrees. A dynamical dependence of the cusp location on the IMF is seen. The cusp is bounded by the cleft, which is characterized by low electron fluxes on closed field lines. Strong accelerations are common in the cleft, e.g., at about 09:00 LT conics are found about 26 percent of the time.

Radar Studies

In recent years the capability to observe the ionosphere from the ground has increased dramatically through the development of radar stations distributed in longitude and latitude (principally in the western hemisphere). Among the observed or deduced physical quantities from radar observations are neutral particle densities, winds, and temperatures, ion convection velocities, electric fields, vertical structure, and electrical conductivities. These variables are central to a consistent description of the ionosphere and to the important field of ionospheric-magnetospheric coupling.

W. Kofman (CEPHAG, France) reported that the neutral particle temperatures inferred from incoherent radar data generally exceed values gotten from widely used theoretical models. The discrepancy could be fundamental and require revisions in theoretical models, or could result from a systematic error in the interpretation of the radar data. Electron temperatures indicate strong heating and very large temperature gradients ($8-12 \text{ K/km}$). The explanation of the large heat flux is not clear;

it may be of magnetospheric origin or relate directly to electron precipitation. Ion temperatures are also found to increase by large amounts above normal (by a factor of 4 to 5, up to 8-10,000 degrees). Interpretations tend to attribute heating to electric fields or electron-ion temperature differences, but the possibility remains that the inference of high temperatures may simply result from an incorrect analysis of the incoherent radar data. The analysis depends on ion composition, and interpretations change dramatically with changing species. For example, changing the ratio O^+ / N from 1.0 to 0.5 would change results by a factor of two or more for large electric fields. High ion temperatures would result from frictional heating in the presence of large transverse electric fields (about 130 mV/m). Non-Maxwellian distributions affect conclusions greatly, and a determination of the scatter spectra for such distributions is under development.

In the past, global representations of ionospheric properties were mainly averaged results gotten from a single radar facility. Convection at high latitudes, for example, can be highly variable, from very weak to very strong, as a function of magnetic activity. J. Foster (MIT) reported on a cooperative effort involving the Sondrestrom, Eiscat, and Millstone Hill incoherent scatter radars to develop two-dimensional, time-dependent mappings of large-scale structures in the auroral ionosphere in place of single-facility averaged descriptions. As an example, Foster displayed observations of the high-latitude ionospheric trough in the electron density observed during an aurora-day experiment using the azimuth scan method pioneered at Millstone Hill. The trough was found to spiral downwards in latitude with increasing local time from 78° at noon to 62° at 22:00. The sunward convection was found to extend into the higher density ionosphere at the low latitude side of the trough. With a similar multiradar approach, C. R. Clauer (Stanford University) described an effort to observe convection patterns for an isolated substorm using high time-resolution data.

C. Senior (CRPE, France) discussed statistical model fits to the EISCAT radar data between about 61 to 72 degrees magnetic latitude for different levels of magnetic activity (K_p). The familiar two-cell convection pattern represented the data, and the convection speed increased with K_p . More of the convection cells were found to fall into the field of view of the radar and the dawn-dusk potential differences across the convection pattern were found to increase with increasing K_p , as expected. The extent of the morning and afternoon convection cells were about of equal size. The convection pattern rotated with respect to the noon-midnight meridian (towards morning) with increasing K_p . The electric field was found to penetrate to lower latitudes with increasing K_p . Equipotentials were highly distorted in the region of the Herang discontinuity such that the transition between the morning and evening cells occurred earlier at higher latitudes. Finally, differences between

convection models were pronounced particularly for the north-south component of the electric field.

Theoretical models of ionospheric electric fields and convection patterns normally depend critically upon the Hall and Pedersen electrical conductivities. The latter were discussed by A. Brekke (The Auroral Observatory, Tromso, Norway) who stated that commonly used values of the Hall to Pedersen conductivity ratio were too large for quiet periods and too small for disturbed periods. Models that attempt to calculate the ratio differ in the use of neutral particle densities (which are uncertain by about a factor of two) and particle collision rates. Brekke's formula for the conductivities during quiet times gave a Hall to Pedersen ratio of 1.28 of a small zenith angle and 1.17 for a zenith of 60 degrees. Larger ratios applied during disturbed periods and in the auroral regions of particle precipitation.

The Magnetopause and Reconnection

R. Elphic (UCLA) reported on magnetopause studies made possible by the ISEE 1 and 2 satellites which shared a common orbit with a separation distance as small as 15 to 100 km. The boundary thickness of the magnetopause was expected to be in the range of 1 to 100 km, corresponding to the geometric mean of the gyroradii of typical magnetosheath ions and electrons. The measured thickness was most commonly 10 to 30 times larger. The only parameter found to date that characterizes the thickness is the magnetic dipole latitude. Thus, the physics of the magnetopause thickness is an open question. Much small-scale spatial structure, on a scale less than or about 10 km, is found in the magnetopause boundary; and time-dependent effects are also likely. The boundary moved with bulk speeds most commonly in the range 30 to 50 km/s.

So-called flux transfer events (FTE's) at the magnetopause have been widely touted in recent years as a definitive signature of magnetic reconnection between the IMF and the geomagnetic field. Elphic stated that it is now realized that plasma data and solar wind properties are needed in order to decide that an FTE is real. The FTE evidence suggests that patchy reconnection takes place at the magnetopause. A statistical result is that the duration of an FTE is large for larger separation times between FTE's. C. J. Ferrugia (UK) summarized a modified Petschek model for which reconnection signatures included FTE's, high-speed flow regions, and spikes in the magnetic field component tangential (northward) to the magnetopause.

J. B. Blake (Aerospace Corporation, US) and D. G. Siebeck (APL, US) reported on multisatellite observations of energetic particles. Blake emphasized great depression events (i.e., magnetic storms) for which satellites at the synchronous distances could be beyond the mag-

netopause and reported evidence for particle leakage and acceleration at the magnetopause. Siebeck reported on event and statistical studies and stated that merging is not necessary for the energization of particles. Energetic particles in the magnetosheath are almost always consistent with a magnetospheric source. He concluded from observations that the magnetosphere is the dominant source of energetic particles in the magnetosheath.

Field-Aligned-Currents

Statistical studies have shown that there are two large-scale regimes of adjacent magnetic field-aligned-current (FAC) systems of opposite polarity. These are the so-called region 1 (RI), and region 2 (RII) current systems, where RI currents at high latitudes are believed to originate at the magnetopause and RII at lower latitudes from some internal plasma regime such as the equatorward boundary of the plasma sheet. J. Slavin (GSFC, NASA) presented analysis of DE-1 and DE-2 satellite magnetometer data to study simultaneous FAC signatures at high and low altitudes. The satellites are suitable for such a study because of the coplanarity of the DE-1 and DE-2 orbits and the high sensitivity (1.5 nT) and sampling rate (16/s) of the magnetometers. Event studies indicated that RI and RII currents were well represented by semi-infinite sheets, the magnetic signatures were larger at lower altitudes in the amount required by current conservation, and RII currents exhibited stability over time scales of about 10 minutes whereas RI currents changed more rapidly with a 1-minute time scale.

In a study with similar objectives, M. Kivelson (UCLA) compared low altitude signatures of FAC's gotten from MAGSAT data with FAC's gotten from and mapped by the Tsygenenko magnetic field model. The comparisons highlighted the difficulty of obtaining accurate mappings from even intermediate distances in the magnetosphere to low altitudes. RI currents seemed to be at unusually low altitudes, to map to the magnetopause, and to exhibit more stability on the dayside than the nightside.

T. Potemra (APL) who has been a major contributor to our knowledge of FAC's stated that event studies have suggested further properties of the current systems: auroral bright spots seem to occur at the reversal location of both FAC's and convection; auroral arcs relate to the RI system; RI currents map into the low-latitude boundary layer in the plasma sheet boundary layer; and FAC's in the cusp are not associated with auroral features and probably map or connect to the mantle. C. R. Clauer (Stanford University) reported on a study of FAC's in the cusp using ground-based and satellite data. The cusp currents respond to changes in the IMF and a high latitude model of ionospheric effects is being developed.